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ABSTRACT

Science educators have reclaimed the importance of educating to promote a scientifically literate society. Project ICAN: Inquiry, Context, and Nature of Science is a professional development project designed to enhance middle and high school science teachers' knowledge and pedagogical skills that directly address the reform's call for student achievement in scientific inquiry and nature of science. Through continued teacher support, Project ICAN aims to enhance teachers' abilities to improve students' understanding of the nature of science and students' understanding of, and ability to perform scientific inquiry within a context of a standards-based science curriculum. Previous efforts have focused on either teacher knowledge or student achievement relative to scientific inquiry and nature of science. Project ICAN represents a first attempt to couple teachers' professional development relative to the nature of science and scientific inquiry with an extended focus on teachers' classroom practice and student achievement. The purpose of this paper is to describe the effectiveness of Project ICAN on student achievement for year 1 of the project. (Contains 14 references.) (Author/MVL)

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EXPLICIT/REFLECTIVE INSTRUCTIONAL ATTENTION TO NATURE OF SCIENCE AND SCIENTIFIC INQUIRY: IMPACT ON STUDENT LEARNING

ED 465 622

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Introduction

Science educators have reclaimed the importance of educating to promote a scientifically literate society (American Association for the Advancement of Science [AAAS], 1993; National Resource Council [NRC], 1996, 2000; National Science Teachers Association [NSTA], 1989). Upon close consideration of the reform's vision for k-12 science education, one finds the emphasis extends beyond calls for students to have basic knowledge of scientific concepts and methods of scientific investigations. Understanding basic tenets about scientific inquiry (SI) and nature of science (NOS) are at the core of scientific literacy. In particular, the National Science Education Standards [NSES] (1996) states that "inquiry is central to science learning" (NSES, 1996, p. 2) and that "students should develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture" (NSES, 1996. p. 21). Research has shown that teachers typically lack views of NOS or knowledge about SI that are consistent with those advocated in reforms, and even our most expert teachers have difficulty creating classroom environments that help students develop informed views of NOS and SI (Lederman, 1992; McComas, 1998; Minstrell & van Zee, 2000). *Project ICAN: Inquiry, Context, and Nature of Science* is a professional development project designed to enhance middle and high school science teachers' knowledge and pedagogical skills that directly address the reform's

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call for student achievement in SI and NOS. Through continued teacher support, Project ICAN aims to enhance teachers' abilities to improve students' understanding of NOS and students' understanding of, and ability to perform SI, within a context of a standards-based science curriculum. Previous efforts have focused on either teacher knowledge or student achievement relative to SI and NOS. Project ICAN represents a first attempt to couple teachers' professional development relative to NOS and SI with an extended focus on teachers' classroom practice and student achievement. The purpose of this paper is to describe the effectiveness of Project ICAN on student achievement for year 1 of the project.

In efforts to foster scientific literacy in the classroom, teachers are asked to approach science instruction in a "constructivist" manner. Constructivist pedagogy is generally accepted as an approach that engages and utilizes students' existing knowledge in such a way as to build upon and/or reframe the existing construct to incorporate new knowledge. The focus in such a classroom is on helping students to understand, test, and revise their ideas; stresses the function of the social community in the negotiation of meanings and the growth of knowledge; and gives students increasing responsibility for directing important aspects of their own inquiry (Smith, Maclin, Houghton, & Hennessey, 2000). Research on teaching of NOS has demonstrated the effectiveness of a constructive approach with an explicit/reflective emphasis on aspects of NOS in relation to inquiry-based activities, historical examples, and even traditional school-science activities (reviewed by Abd-El-Khalick & Lederman, 2000). Similar results have been reported for learning *about* SI (Schwartz, Lederman, & Thompson, 2001).

Schwartz and Lederman (2002) proposed an emerging model of critical elements for the development of effective pedagogical content knowledge (PCK) for NOS and application of that knowledge in the classroom. Knowledge of NOS, knowledge of science subject matter, and

knowledge of pedagogy are just three of the elements that blend to form PCK for NOS. However, the complexity of this blend is not well understood and is the subject of extended research. In addition to this knowledge base, teachers also need to express purposeful intentions to address NOS and SI within their classroom and maintain positive self-efficacy and outcome expectancy for their NOS/SI teaching efforts (Figure 1).

Research supports the claim that through purposeful and explicit/reflective instruction of NOS aspects and connections of aspects within the context of science activities that are familiar to students (both classroom-based and real-world examples), students are able to understand aspects of NOS as deemed relevant by the science education community (Abd-El-Khalick & Lederman, 2000; Carey & Smith, 1993; Khishfe & Abd-El-Khalick, 2000; Smith et al, 2000). Similar outcomes are suggested for learning about SI (e.g., Schwartz, Lederman, & Thompson, 2001). An explicit/reflective approach incorporates questioning and guided reflection to draw learners' attention to relevant aspects of NOS and SI in the context of inquiry-based activities or historical examples. These considerations of effective teacher development and classroom practice informed the design of Project ICAN.

Project ICAN: Design and Focus

Design

Project ICAN comprised a three-week summer institute followed by monthly workshops during the academic year. The summer institute focused on developing teachers' pedagogical content knowledge for NOS and SI (Schwartz & Lederman, 2002). There were thirteen teacher participants (8 middle, 5 secondary, and 1 middle/secondary). Teachers participated in sessions focusing on NOS, SI, and unified concepts through a series of explicit/reflective activities, readings, and discussions. In addition, teachers engaged in a science research internship with

practicing scientists. This research experience was the subject of reflective journal writings and discussions designed to enhance teachers' understanding of inquiry and NOS within an authentic context. During the third week of the institute, teachers revised and practice taught lessons they would use during the academic year in their own classrooms.

During the academic year, teachers video-taped a monthly lesson, and collected lesson plans, reflections, and student work for project staff to review and provide feedback. Staff conducted on-site classroom observations to provide individualized feedback. A selection of video-taped lessons were presented to the group during monthly workshops, providing opportunities to discuss teaching contexts, offer peer support and feedback, and identify growth in their own and others' teaching. Teachers shared NOS and SI teaching experiences, discussed ways to further enhance lessons, and reported on student outcomes. Further details of Project ICAN summer institute and workshop activities are provided in another AETS 2002 session and paper (Lederman et al., 2002).

Focus: Definitions and Teaching Approach

Nature of Science

The "nature of science" refers to the epistemology of science, or science as a way of knowing. We acknowledge that there is not one single "nature of science" that fully describes all scientific knowledge and enterprises. There are various representations of NOS affirmed by historians, philosophers of science, science educators, and others, and it should also be noted that these representations are as tentative as the knowledge and enterprise of science itself. However, we contend that there is general agreement concerning certain aspects of NOS that are relevant and accessible to K-12 students.

Chief among these is that scientific knowledge is

- *tentative* or subject to change and revision.

Reasons for the tentative NOS stem from several other aspects including:

- scientific knowledge has basis in *empirical evidence*,
- empirical evidence is collected and interpreted based on current scientific perspectives (*theory-laden* observations and interpretations) as well as *personal subjectivity* due to scientists' values, knowledge, and prior experiences,
- scientific knowledge is the product of human *imagination and creativity*, and
- the direction and products of scientific investigations are influenced by the society and culture in which the science is conducted (*sociocultural embeddedness*).
- Additional important considerations to NOS include the differences between *observation and inference* in the development of scientific knowledge, and
- the differences between and functional roles of scientific *theories and laws*.
- These aspects are not mutually exclusive, but quite interdependent.

These aspects of NOS, although considered "science content," are relevant to the more "traditional" science content recommended for K-12 science education, and as such, *can and should be taught in conjunction with traditional science subject matter*. These agreed upon characteristics of the scientific enterprise provide a framework for teaching about NOS and SI and, in turn, describe what students should come to understand. Such understanding is a necessary component of scientific literacy. It is important to note that this list is neither all-inclusive nor discipline-specific, but represents those NOS aspects believed to be relevant to general K-12 science education and advocated in current reform documents.

Scientific Inquiry

As stated in the NSES, (NRC, 1996)

> "Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. Students will engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world, but they also should develop the capacity to conduct complete inquiries." (p. 23)

In addition to being able to conduct inquiries of various types, the NSES also promote students' understanding about scientific inquiry (NRC, 2000). This understanding includes

- knowledge about various methods of investigation (there is no single "scientific method"),
- understanding of the placement, design and interpretation of investigations within research agendas (current knowledge and direction guide investigations),
- recognition of assumptions involved in formulating and conducting scientific inquiries,
- recognition of limitations of data collection and analysis in addressing research questions,
- recognition and analysis of alternative explanations and models,
- understanding of the reasons behind the use of controls and variables in experiments,
- understanding of distinctions between data and evidence,
- understanding of relationships between evidence and explanations and the reliance on logically consistent arguments (based on historical and current scientific knowledge) to connect the two,
- understanding of the role of communication in the development and acceptance of scientific information

It is important to note that there is necessarily an overlap between the targeted aspects of NOS and aspects of scientific inquiry. However, even though NOS and scientific inquiry are interrelated concepts, they each need to be addressed explicitly. An understanding of one does not ensure an understanding of the other. The distinctions between NOS and scientific inquiry (or science process) need to kept clear. Conflation leads to reliance on implicit messages to teach one or the other.

An Explicit/Reflective Approach

An explicit/reflective approach to teaching NOS and about SI is emphasized throughout the program. An explicit/reflective approach to teaching NOS/SI is advocated and sought by the researchers as the desired approach to teaching about NOS/SI. An *explicit* instructional approach advances that the goal of improving learners' conceptions should be stated clearly and planned for, rather than be an expected outcome that relies on implicit messages. This approach intentionally draws learners' attention to relevant aspects of NOS and SI through instruction, discussion, and questioning. The term "explicit" should not be considered synonymous with "didactic." Explicit is used here to emphasize that teaching about NOS and SI should be treated in a manner similar to teaching about any other cognitive learning outcome. NOS and SI understandings should be intentionally planned for, taught, and assessed rather than be expected to emerge from teaching science content or process skills, or engaging students in science activities. The *reflective* component involves the application of these tactics in the context of activities, investigations, and historical examples used in daily science instruction. Thus, an *explicit/reflective approach* involves *purposeful* instruction of NOS and SI through:

- discussion;
- guided reflection;

- specific questioning;
- in the context of classroom science activities (including inquiry-oriented activities, examples from history of science, and traditional classroom-based science activities).

Data Collection and Analysis

Video-taped lessons, lesson plans, and classroom observations comprised the data for examining teacher NOS and SI teaching. Data were reviewed for explicit attention to aspects of NOS and SI. Student learning with respect to the targeted aspects of NOS and SI was assessed in a pre/post administration (beginning/end of academic year) of the Views of Nature of Science (VNOS-C for students) (Lederman, Abd-El-Khalick, Bell, Schwartz, & Akerson, 2001) and the Views of Scientific Inquiry (VOSI for students) questionnaires (Schwartz, Lederman, & Thompson, 2001). At least one class for each teacher was included in the analysis (around 800 students, grades 6-12). The NOS aspects assessed for students in Year 1 of Project ICAN include that science is a) tentative, b) based on empirical observation, c) influenced by subjectivity (both personal subjectivity and theory-laden observations/inferences), d) the product of human inference and creativity, and e) comprised of theories and laws. Aspects of SI targeted on the VOSI include a) multiple methods and purposes of investigations, b) importance of consistency between evidence and conclusions, c) multiple interpretations of data are possible, d) distinctions between data and evidence, and e) data analysis is directed by the questions of interest, involves representation of data and the development of patterns and explanations that are logically consistent. Other classroom assessments that specifically addressed NOS or SI were examined to enrich the description of student outcomes. Data for each student were analyzed to provide details of trends and shifts in students' views of the targeted aspects of NOS and SI. Class data

were pooled to describe project outcomes. Although some percentages are approximated, specific quantitative data were not sought in this preliminary analysis.

Results

The primary purpose of this report is to describe trends and shifts in students' views of NOS and SI. Although reported here in brief, the impact of Project ICAN on teachers' knowledge of NOS and SI is the subject of another investigation (Lederman, et al., 2002). In general, 85% of the teachers demonstrated enhancements in NOS and SI views. These teachers varied in their instructional attempts and student outcomes.

Students' Pre-test Views of NOS and SI

In the interest of time and space, suffice it to say that the students in this study held pre-test views of NOS and SI that were naïve and realist. Students of all levels tended to view science as having "right" answers and finding the one true explanation of the world. This tendency was seen in student explanations of controversy in science (e.g. competing theories of dinosaur extinction). They viewed multiple interpretations as resulting from errors or incomplete data. Once all the data are collected, the answer is revealed. The students tended to view change in science as coming in the form of building upon existing knowledge (as opposed to change from shift in perspective). Regarding methods of science, students tended to view experiments in a broad sense. They saw all science as experiments because that is what one does in science. Examples of scientific experiments included simple frog dissection to "seeing what happens when you mix vinegar and baking soda."

Teaching Attempts and Student Outcomes

Eleven of the 13 (85%) of the teachers showed great improvement in their abilities to explicitly address NOS and SI within the context of Standards-based science subject matter. The monthly review of lessons, videos, and accompanying discussions demonstrated substantial

growth from month to month. Teachers recognized their successes as well as challenges, and they shared their experiences openly with the group. Through the monthly workshops it became evident that the teachers had formed a peer support group where they valued their interactions and worked to progress together. Great efforts were made to establish and maintain a comfortable atmosphere wherein teachers were able to share concerns as well as success stories.

One of the teachers who showed no improvement dropped from the program half way through the year. The other teacher maintained fairly naïve views, but high self-efficacy. In other words, he thought he understood NOS and SI as well as how to teach these concepts, but assessment results and classroom observations indicated otherwise. Lacking recognition of his own weaknesses in NOS and SI conceptions and PCK, this teacher did not develop in the desired direction to the extent the other teachers did. Although he possessed a high self-efficacy with respect to his knowledge and classroom practice, the ultimate results in terms of student outcomes were far less than desirable, which was due to the lack of explicit integration of NOS or SI aspects within his teaching.

Nature of Science

Most commonly taught were aspects of observation and inference, subjectivity, tentativeness, empirical-basis, and creativity. Much less frequent was the difference between theory and law. Teachers reported ease of inclusion, or seeing where the aspect "fit" with their lesson, allowed them to explicitly address some aspects more than others. Additionally, their own level of understanding of NOS and SI and comfort with the subject matter and activity style reportedly influenced teachers' efficacy as well as method of teaching various aspects. For example, most easily taught seemed to be the difference between observation and inference. Similarly, this aspect seemed to be the easiest for the

teachers to understand themselves and they saw frequent opportunities to express the distinction during their lessons.

Instructional approaches included didactic methods (simply telling students "science is tentative" or "It is important in science to back up conclusions with data.") as well as whole-group discussions within the context of a demonstration or an inquiry-based laboratory activity. Subject areas included generic NOS activities and content-embedded activities such as classification, natural selection, ecology, genetics, weather, and forces and motion. Details of teacher lessons are to be provided in a subsequent report.

Between 30% and 50% of the students whose teachers explicitly addressed NOS showed more informed views of at least one NOS aspect. The most significant changes in students' views were with respect to the inferential, subjective, and tentative aspects of NOS. Variance among classes correlated with teacher emphasis. For example, the teacher who seemed to teach observation/inference on almost a daily basis had students who used the words "observation" and "inference" in their post-test written responses as activities that scientists do and to support their claims for an investigation being "scientific."

> [Science is…] *"observatioins, inferences, models, dissections, how things in nature and animal life work."*
>
> *"Scientists experiment and make observations and inferences."*

In response to a question about whether or not the activity of looking at different birds and their food source to make conclusions about beak shape and preferred food is "scientific" or not, a student answered,

> *"Yes, because he took observations and inferences and made a description. Just like a scientist."*

A notable change in students' views was in their acceptance of subjectivity in interpreting data. This NOS aspect necessarily overlaps with scientific inquiry's "valid multiple interpretations" aspect. Pre-test data indicated students tended to hold views in one "right" answer and any differences in conclusions were due to lack of sufficient data or errors on someone's part. Post-test data indicate a shift (almost twice as many post-test responses compared to pre-test responses) from this absolutist view that data are "all-revealing" to acknowledging personal subjectivity influencing data interpretation. Although a shift in the desired direction, many students presented an "anything goes" view that tended to see any conclusion as valid because people have different opinions and backgrounds. For example, when asked about how different interpretations are possible from the same set of data (given the controversy in dinosaur extinction as an example), responses included:

"They have different opinions."

"We all have different minds"

Some students did indicate their understanding of the inclusion of data in interpretations. These types of responses were considered indicative of more informed views of the empirical basis of scientific knowledge as opposed to an "anything goes" view.

> *"Everybody has different ideas about everything. They could come to different conclusions because they could interpret the information differently..."*
>
> *"[Different conclusions from the same set of data are possible because] they might put together the information different."*

Regarding tentativeness of scientific claims, students demonstrated mild shifts from realist views *("There is only one right answer in science.")* to indicate recognition of possibility of change in the future *("We don't know anything exactly. Everything changes")*. However, change was mostly due to new technology and new findings. At this point, scientific knowledge was seen as building on itself and is self-correcting.

[Scientific knowledge may change in the future because…]

"Scientists will find new things and better explanations."

"I think information will change because things change and scientists will come up with new theories and find more info out and will keep finding new things."

Some students expressed change in terms of the world changing, not just our understanding of the world.

[Scientific knowledge may change in the future because…] "we will have new technologies and many new species."

"I think it will change in the future because like if animals have offspring with different breeds the offspring will turn out different than usual."

Few students exhibited more informed views with respect to the distinction between theories and laws. This aspect was rarely taught, even though most of the teachers had a firm grasp of the differences AND given the clear connection to the distinction between observation and inference. Teachers reported a lack of context for teaching about theories and laws. Those who taught physical science tended to make mention of theories and laws more frequently than those teaching life science. Yet, still little explicit attention to the distinction between theories and laws was provided. In general, students held two types of views. First, they had views of theories and laws as having different levels of "proof" behind them whereby theories are simply guesses and laws are proven true.

"A theory that we don't know if it's true or not. Example: In the year 2030, there is going to be a huge earthquake in Oregon. A law is something we know is true. Example: There was a big flood in Texas."

"A theory is a guess and does not have a lot of facts behind it. Example: The dinosaurs were killed by a comet. A law is something that is proven by facts. Example: The dinosaurs died out."

"A theory is what scientists guess on something. Example: dinosaurs. A law is a fact about an organism that is true. Example: How DNA works."

Second, some students understood the terms in the everyday vernacular use and applied this understanding to science. For example, theories were guesses or possible explanations. Laws were "passed by scientists" and "rules that scientists follow." For example,

" A scientific law is a rule that scientist follow. Example: Wear an apron."

Some students demonstrated mild advances in their understanding of theory and law. Outcomes varied by teacher. Still less than 10% of the students indicated informed understandings of this aspect.

Scientific Inquiry

Eighty-five percent of the teachers, as compared to 30%- 45% of their students, demonstrated major changes in their views of SI during the course of the project. At the start of the program, most of the teachers believed that SI involves a set and sequence of steps that will objectively lead to one right answer. This is traditionally referred to as "the Scientific Method." During the project, most of the teachers came to acknowledge that there are multiple methods of scientific investigations. This realization was reflected in their teaching. One teacher expressed his view of scientific inquiry and the traditional way he used to teach as, *"The thing about the Scientific Method is it sucks all the humanity out of science."* This teacher changed the way he approached inquiry instruction in his 8th grade physical science class by encouraging students to be more independent in what and how they investigate. This teacher also incorporated more historical examples into his lessons. The majority of his students expressed an understanding of multiple methods of investigations and that science is a human endeavor, with room for "error" and interpretation. However, this teacher placed little explicit emphasis on any other aspects of NOS or SI. He assumed his students would come to understand the meaning of tentativeness of

scientific knowledge and the role of subjectivity by learning about the historical cases he presented.

The teachers conducted several inquiry activities in their classrooms that were followed by explicit discussions of inquiry and NOS. About 40% of their students showed enhanced understandings of multiple methods of investigations. However, few were able to give concrete examples of differences. Again, grade level and subject varied. In response to the question about the bird beak investigation, students who demonstrated understanding of multiple methods tended to respond such as:

> *"Yes the investigation is scientific because he is trying to find out more about the birds. It isn't an experiment because he doesn't mix anything together and test it."*

> *"It is scientific because he makes observations and conclusions. It isn't an experiment because he doesn't test anything new."*

All teachers demonstrated more informed views of the multiple interpretations of a given set of data. However, only 60% of these teachers explicitly addressed this aspect in their classroom practices, although inconsistently. About 30% of the student exhibited more informed views of this aspect.

Question: If several scientists working by themselves ask the same question (for example, they all want to find out why volcanoes erupt), will they come to the same conclusions? Why or why not?

> *"No, because they could all have heard, learned, or know different information that would help them come to different conclusions."*

> *"No, they all have different minds."*

When asked if their response changes if the scientists are working together, a response indicative of considering the role of communication and conviction in science included:

> *"Yes, because then they could all give their view and understanding and reasoning on what they think and why."*

Some students maintained naïve views regarding data interpretation. They think that given the same data, scientists should come to the same conclusion. It is what we call a "seeing is believing" position. The data in effect *is* the answer for these students. Careful consideration of questions, analysis, and inference are not clearly acknowledged by students with this view. This view was typical of pre-test responses. Although up to 30% of the students showed enhanced understandings of subjectivity and valid alternative interpretations, this naïve view was still prevalent in many post-test responses. Examples of representative responses include:

> *"If all the scientists are using the same procedures to collect data, they most likely will come to the same conclusions if the get all the same data."*

> *"They are all looking at the same information so they would all get the same conclusion."*

To their credit, teachers recognized their instructional inadequacies regarding explicitly acknowledging alternative conclusions. They attributed their difficulties to lack of examples relevant to classroom investigations. This result is evident of simplistic inquiries where one general conclusion is likely. Lesson observations were thusly consistent. Teachers needed and wanted examples of data sets where more than one conclusion could be reached and accepted. This limitation was perhaps due to subject matter wherein teachers wanted students to reach one answer that was consistent with accepted scientific knowledge.

All teachers demonstrated more informed understandings of the role of evidence in supporting conclusions, and 85% of these teachers explicitly emphasized this aspect during instruction. Emphasis, however, was sporadic and context-dependent. Again, teachers had difficulty in recognizing opportunities to teach about this aspect within daily instruction. They reported having a set of questions to guide planned classroom discussions following laboratory activities wherein students collected data and formulated conclusions. Such discussions rarely

involved all the students and time constraints limited extension beyond the classroom context. Students demonstrated somewhat more informed views.

Distinctions between data and evidence are often overlooked in the science classroom. Understanding the difference, that evidence is the data or pattern from the data that is useful in supporting one's conclusions, should be helpful for students in their understanding of the importance of connecting conclusions with evidence. Furthermore, making the distinction explicit in the classroom likely helps students with formulating arguments necessary to support their own conclusions. Pre-test responses indicated students either had no idea what data or evidence meant or they tended to use the terms as synonyms. Post-test responses indicated slight shifts toward recognizing differences between the terms and their purposes.

> *"Data is information. Evidence is something you can use to support a question."*
>
> *"Data is information. Evidence explains stuff."*
>
> *"Data is what you collect. Evidence proves something."*

Regarding data analysis, few students attempted to answer the question. Those who did indicated data analysis involved graphing or "looking at your data to find your answers."

The creation and use of scientific models and modeling was emphasized in Project ICAN and several teachers were able to include relevant explanations and discussions during the academic year. One teacher of grade 7 life science took an opportunity to discuss models during her lesson on natural selection. The activity involved students as "predators" and dots of paper of various colors as "prey" on various patterned fabric backgrounds ("environment"). Students did several rounds of "feeding" to determine the survivability of different colored "prey" in selected "environments." The teacher used this activity to discuss models and modeling in science. She asked students about the purpose of the

modeling in explaining and making predictions about what happens in real world environments. Compared to pre-test data, post-test data contained more references to models in science.

> *"[Scientists] make models of what they are working on. Then they predict about it."*
>
> *"Scientists do experiments, study life and make observations and models."*
>
> *[A scientific experiment is] "studying of something using models and info they have researched."*

Conclusions and Implications

Overall, students' conceptions of NOS and SI showed some advancement. The results reported here are trends identified from preliminary analysis of student data. The extent of advancement and relationships among teaching styles, context, grade level, and conceptions have not been sought at this point. The approximated degree of advancement is not as compelling as we had hoped, but encouraging lessons were learned. Most advances were with respect to the inferential, subjective, empirical, and tentative aspects of NOS and multiple methods, multiple interpretations, and the difference between data and evidence. It appeared that these aspects were more easily integrated into teachers' classroom practices, as they reportedly "fit" more appropriately within a wide range of contexts. Students' views related to the distinction between theories and laws, the importance of connecting evidence with conclusions, and understanding of data analysis remained more naïve. These aspects proved to be more difficult to explicitly incorporate into daily instructional practice for the ICAN teachers. The transition from an absolutist "one right answer" view to one of "anything goes" has been reported elsewhere as a step towards a full transition to understanding the inherent tentativeness, subjectivity, and creativity involved in scientific knowledge (e.g. Lederman et al., 2000; Schwartz, Lederman, & Thompson, 2001; Schwartz & Lederman, 2002).

Results of this study are consistent with others reporting the myriad of factors influencing effective NOS and SI learning outcomes. The homogeneity of results from grade 6 through grade 12 suggests that grade level is not necessarily a constraint to effective NOS and SI instruction or learning. Teacher knowledge and teacher intentions are key. Those teachers who maintained naïve views of certain NOS and SI aspects were ineffective. Those teachers who held more informed views were not necessarily effective unless they secured these views within their own minds and intentionally within their instruction. Even so, these teachers reported difficulties with consistency throughout their subject matter. Those lessons that were revised during workshops held far more explicit references than other lessons. Comfort with subject matter, time, and features of daily teaching (schedule changes, management, absentees, curriculum constraints, etc.) all impacted teachers' abilities to revise and implement lessons consistently. As such, NOS and SI instruction was more sporadic in occurrence than presented as a unifying theme across the curriculum. These results support the model of necessary requirements for NOS teaching (and SI teaching) and PCK for NOS proposed by Schwartz and Lederman (2002).

One source of particular concern was in classroom assessment of NOS and SI. Often the teachers would include some explicit references to several aspects, but then make the assumption that these aspects were clearly understood by the students. In these cases, teachers asked few questions for clarification, and the explicit references were rarely followed up with discussions or examples. Teachers were not comfortable with assessing students' views in a formative or summative manner. Discussions would be valuable opportunities to formatively assess students' views of specific aspects and connections among aspects and subject matter. It seems for these teachers' first attempts, however, that they were more concerned with generating discussion than really listening and reflecting on student responses. Furthermore, teachers did not feel

comfortable placing value on students' views with formal assessment methods. Part of their concern was their own struggle with the concepts. The teachers' views continued to develop during the academic year. The general feeling was, "How can I assess my students when my own views aren't solidified?" Rather than seeing an opportunity to understand their students better and, in turn, effectively respond to student needs, most of the teachers saw assessing NOS and SI as unfair. This feeling stemmed from their view that assessment places a "right" or "wrong" value on responses. Really, these results are not surprising given the novelty of the teaching approach and content. Reaching a comfort level with teaching and assessing NOS and SI that is conducive to effective instruction and assessment may require small steps toward success, with continuous support. Follow up workshops in coming years of Project ICAN will directly address the issue of assessment and teachers' concerns and perceptions.

Extended peer and professional support was an essential factor in Project ICAN to aid teachers in their development of NOS and SI understanding and pedagogical skills. Student outcomes are encouraging, although there is a lot of room for improvement. The proof will be in the sustainability of these teachers in the years to come to continue their efforts. Further research on progression of student views of NOS and SI and relationship to pedagogy and context is necessary to further advance our understanding of effective pedagogical practices.

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